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Final Report for USDA Agreement No. 16-904-CA Objective No. 5
LINEAR PROGRAMMING FOR LAND-USE AND WATERFOWL MANAGEMENT

by

PATRICIA ANN CHAMBERLAIN

July 23, 1984

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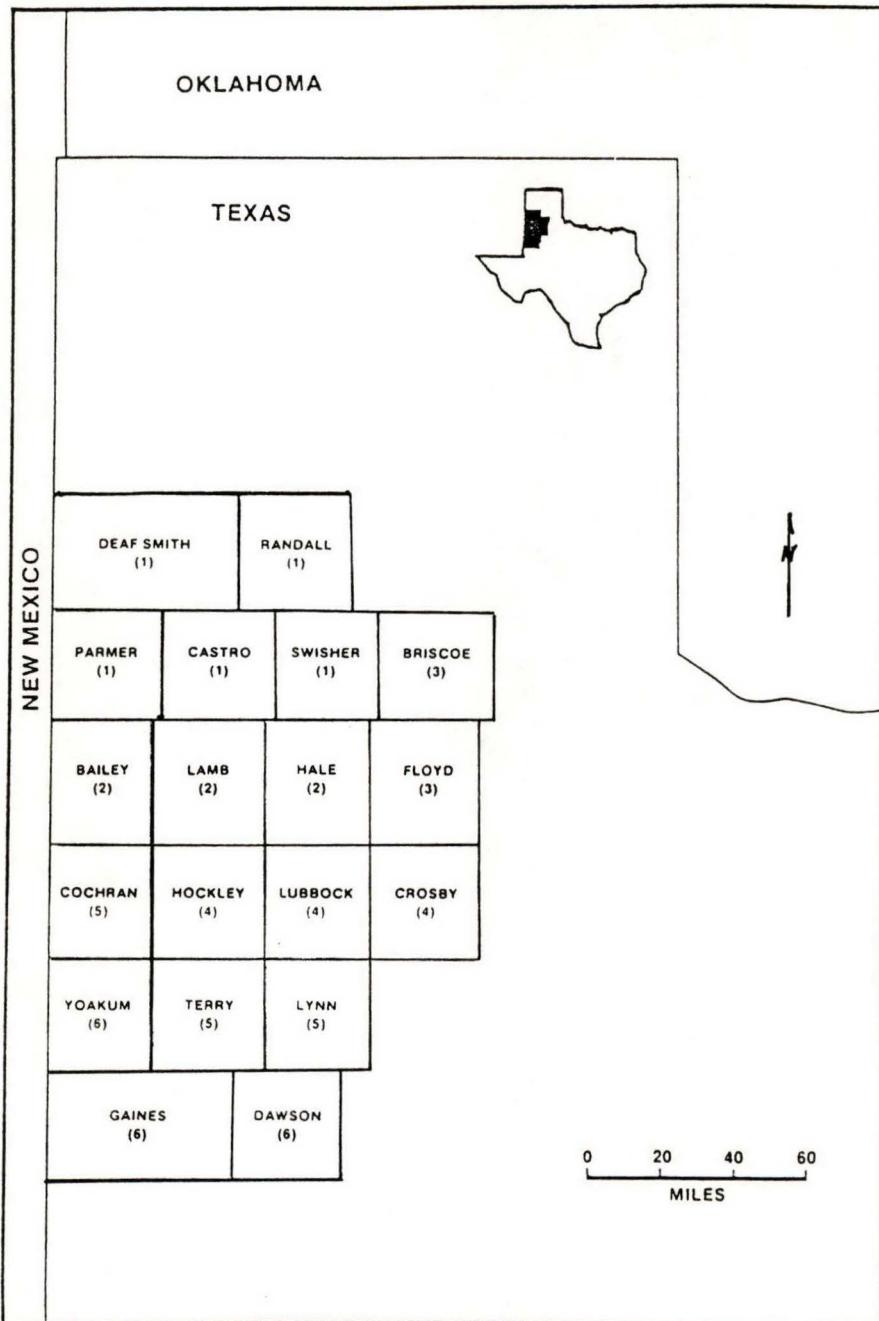
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FINAL REPORT

Introduction

The Texas High Plains is a semi-arid region overlying the Ogallala Aquifer. The aquifer, at present, supplies farmers with a reliable irrigation water source in contrast to surface water which is negligible in the region. Projections of depletion of the aquifer over the next 20-40 years indicate that agricultural crop and management changes will most likely occur. Other activities dependent on a steady water supply will also be affected barring water importation.

The region is also the winter home for approximately a million migratory waterfowl. Playas temporarily concentrate and hold runoff from precipitation and irrigation. These ephemeral wetlands offer resting places for waterfowl and easily accessible tailwater for recirculation to crops.

Agencies responsible for agricultural research and water conservation have developed and are improving irrigation methods that maximize application effectiveness and efficiency. These include low energy precision application (LEPA), furrow diking, and pulse irrigation. If fully implemented, these methods could

substantially curtail runoff from irrigation water and precipitation thus diminishing water in playas needed to secure an adequate wintering ground for migratory waterfowl.

Low precipitation and high evaporation rates place great strain on the water resources available from the Ogallala Aquifer. The threat of eventual exhaustion because of excessive use without adequate recharge (or pollution by saline water intrusion) is not an idle worry (White 1966). Farming is a risky business in the Texas High Plains. Fifty percent of the annual rainfall in semi-arid regions can occur in less than 15% of the days with rain (White 1966). Crop success or failure is completely dependent on proper moisture management. In light of the evaporation rate (1.56-12.58 inches/month, 83.64 inches/year), farming in the High Plains study area is precarious with an annual average precipitation of 16 to 21 inches (see Chamberlain 1984, Table 2.3, also Richards 1979). In Lubbock County from 1946 to 1977, evaporation exceeded precipitation in all but 10 months (Texas Department of Water Resources 1980).

Agricultural managers in semi-arid regions 1) can supplement precipitation for a generally constant yield from crops tolerant of the lowered water availability and greater transpiration rate, or 2) they can use full irrigation to achieve intensive production (Arnon 1972). Full irrigation may offer the greatest opportunity for maximizing the return on investment of resources. Irrigation can

assist in risk avoidance, but high energy prices and limited water resources can hinder the decision-making process (Lacewell 1976). Shifts in commodity prices also make pre-plant and pre-harvest decisions even more difficult. Potential profitability of the total farm management program can be greatly affected by resource-allocation decisions. The goal of the farmer is generally to maximize profit.

Organizations such as the High Plains Underground Water Conservation District (No.1) are authorized by Texas law to promulgate rules and regulations affecting use of water from the Ogallala (Tex. Water Code Ann., Sec. 52.001-.023, Vernon Supp. 1984). "(W)ilfully..." allowing irrigation water to escape into any "...river, creek, natural watercourse, depression, lake, ...road, or road ditch..." is a form of waste (Tex. Water Code Ann., Sec. 52.001, Vernon Supp. 1984). However, water from the Ogallala may be used for recreation (Tex. Water Code Ann., Sec. 52.001, Vernon Supp. 1984).

One potential solution to the division between the agricultural interests wanting to eliminate all runoff and those persons interested in maintaining habitat for wintering ducks and geese lies in making waterfowl hunting a viable economic activity. Two problems can be mitigated simultaneously by integrating wildlife into the High Plains farm plan: 1) water waste can be reduced and 2) enhanced

wintering waterfowl habitat can be maintained. The most conservative irrigation program currently available--using furrow dikes and specialized application equipment--could be installed. The amount of pumped water would go down (along with energy costs) and the crop yield per acre would increase (Cross Section 1983). Then playas would be dependent on direct precipitation (without runoff) and whatever the farmer chose to add as a supplement for recreational purposes. Waterfowl fee-lease hunting would make the latter course profitable.

A linear programming model was developed for a conservative test of the situation. Budgets for the predominant crops on the Texas High Plains (Chamberlain 1984) were used in combination with budgets for hunting enterprises (Chamberlain 1984) to determine whether there could be integration resulting in 1) an increase in the net revenue above variable cost for the whole farm plan and 2) a more secure water supply for the birds.

Objective

The objective of this study was to:

develop a linear programming model
usable by farmers and wildlife
professionals integrating lease
hunting, waterfowl habitat management,

and optimal crop combinations on the Texas High Plains.

Methods

Linear programming (LP) requires that crop activities be defined in terms of the physical resources required to support production and the cost per unit of resource. The study area was composed of 19 counties extending from Deaf Smith County on the north to Gains County on the South, and from the New Mexico state line to Briscoe, Floyd, and Crosby counties on the east. Crop budgets developed for the Texas High Plains study area (Chamberlain 1984, Appendix B) supported construction of 12 model scenarios. Cash flow and machinery-use charts were used to derive the coefficients on a monthly time frame for each crop by the acre.

Constraints for the model were derived from the data bases established in Chamberlain (1984). Total land available for each scenario was that amount of land in the large and small-sized typical farms for each subregion. Irrigated crop acres represented the maximum "irrigable land" for each typical farm. A method of percentage conversion of crop land to playa land was developed. If not used, the total amount of land would have exceeded the limits defined for the typical farm size and defining the constraint for

irrigable acres would have been impossible (Chamberlain 1984). The variables are defined in terms of the code for the LP model.

$$\text{TOTLAND} = \text{LANDDRY} + \text{LANDIRR} + \text{LANDPLY}$$

$$\text{IRR\%} = \frac{\text{Irrigated acres - typical farm}}{\text{Total acres in the typical farm}} \times 100$$

$$\text{DRY\%} = \frac{\text{Dryland acres - typical farm}}{\text{Total acres in the typical farm}} \times 100$$

$\text{LANDPLY} = (\text{Acres of average playa}) \times (\text{number of playas on the typical farm in the region.})$ Small typical farms were assumed to have half the average number of playas as large farms for the same subregion.

$$\text{SUM} = \text{Reduced land sum} = \text{TOTLAND} - \text{LANDPLY}$$

$$\begin{aligned}\text{Therefore: } \text{LANDDRY} &= \text{SUM} \times \text{DRY\%} \\ \text{LANDIRR} &= \text{SUM} \times \text{IRR\%}\end{aligned}$$

Because government sources give all data in terms of acres actually farmed, the amount of land needed to allow for turn rows, roads, or farm buildings was omitted. Dryland had no upper bound. Excess irrigable land could be converted to dryland farming if irrigated crop activities were unprofitable or infeasible.

The amount of water available from the Ogallala Aquifer for irrigation was assumed to be limited by 1) the amount that could be pumped, and 2) the number of hours that a typical pump could operate, taking into account the down-time needed for repairs and

maintenance. The amount of water available was determined from the Texas Department of Water Resources record analysis in Chamberlain (1984). The amount varied according to the average calculated for each subregion (Chamberlain 1984, Table 2.10). Farm irrigation averages were based on 24-hour pumping. The number of hours that each pump was capable of running was estimated as 85% of the available hours with 15% down-time (Stoecker pers. commun.).

$$\begin{aligned} \text{H2OIRR} &= \text{Aquifer yield in (Ac. x Ft.)/(Day)} \\ &\quad \times (12 \text{ In./Ft.}) \\ &\quad \times \text{Number of wells per unit acre} \\ &\quad \times \text{Number of acres in the typical farm} \\ &\quad \times 365 \text{ days per year} \times (1-0.15) \end{aligned}$$

$$\begin{aligned} \text{H2OIRR}_i &= \text{H2OIRR}/12 \\ i &= 1, 2, \dots 12 \text{ month} \end{aligned}$$

The number of wells per county was taken from the report of irrigation practices on the Texas High Plains by New (1977). The number of wells per unit acre was calculated by dividing the total number of wells in the county by the total number of acres of irrigable land. The amount of irrigable land was assumed to be equal to the acres irrigated plus the irrigable acres not irrigated.

The labor constraint was based on 2080 hours per person per year. The large farm model was assumed to have 3 man-years of labor available or 6240 hours per year. Small farms were constrained to 2 man-years (4160 hours per year). The amount of labor available was

assumed to be evenly distributed over the course of the year.

Irrigation labor was 0.10 hour per acre-inch of water applied to all crops. Pump labor was set at 0.05 hour per acre inch of water pumped for the hunting activities. The labor coefficients for each activity combined "other" labor with machinery and irrigation labor from the cash flow tables. The labor constraint was applied to both crop and hunting activities.

Capital to support production was handled in two ways, by cash transfer and cash borrowing. Cash transfer columns were used to allow income from one month to be transferred to the next month to defray production expenses prior to forcing (or allowing) the farm operator to borrow money at a positive rate of interest.

$$\text{EOBi} + \text{CBi} = \text{EXPi} + \text{UEXPCi}$$

where: EOBi = the amount of operating cash available at the beginning of period i

CBi = the amount of borrowed cash in period i

EXPi = the amount of production expense in period i

UEXPCi = the amount of unexpended cash at the end of period i

The amount of borrowed cash was calculated in the model as the principal plus the interest on a monthly basis. The farmer was assumed to refinance each month any of the previous month's balance that could not be repaid. An interest rate of 18% (APR) was assumed.

The First National Bank of Lubbock (Mr. Mike Coomer) was contacted to establish a credit constraint. A "general-rule-of-thumb" of 60% of the expected gross revenue for each crop pattern is considered the credit limit. Banks will loan up to 80% of the production capital (during hard times) but prefer to stay under the 60% level. Therefore, the model was constrained by a credit limit (CBR_i) of 60% of the possible revenue if the entire farm was planted in the most valuable crop (dryland and irrigated) without regard to other constraints. Fixed costs were not considered.

The ending balance (ENDBAL) for each activity was merged with the capital expenditure in the monthly LP row that occurred two months following harvest. The ENDBAL row then contained only those figures relative to cash transfer and borrowing in the twelfth month. The ENDBAL for hunting activities was entered in the monthly row of capital expenditure equal to the month of receipt because no marketing lapse was assumed to occur.

Waterfowl hunting enterprise budgets for day, season, and yearly fee-lease activities (Chamberlain 1984) were used for coefficients estimating the quantity of resource factors sustaining the enterprises over the 12-month planning period. A transfer row was added to the model when hunting was included, allowing waste corn to be transferred from irrigated corn production to the hunting enterprises at the Stage 2 level. An assumption was made that the

level of available corn in the scenario without playa land would be the minimum amount allowed to enter the model if hunting at Stage 2 was selected. This assumption was made to maintain waste corn as a waterfowl management asset. The average amount of initial corn waste available to waterfowl prior to any type of post-harvest farm management procedure is about 364 kg/ha (or 147.31 kg/ac) (Baldassarre et al. 1983).

The DUCKFOOD transfer row allowed 147.31 kg of waste corn to become available for each acre of irrigated corn that entered the farm plan. No difference was assumed to exist in the amount of waste on the fields because Baldassarre et al. (1983) found the amount of waste to be a function of corn moisture content at harvest. Moisture content is a variable selected by the farmer and does not depend on the method of irrigation. The amount of DUCKFOOD required in each Stage 2 hunting activity was 39,639.64 kg for the season. Resources added to the model by any crop activity enter as negative values, and resource requirements (or uses) are positive. This change of sign applies to all except the gross margin row (C row) where a positive sign means value is added to the final optimal solution. A negative value in the C row does not add to gross margin unless an intermediate product is used by another activity.

The gross margin from each optimal solution and the profit maximizing acreage (or level) of each activity included in the farm plan are presented in Tables 1-5.

The Model

The linear programming model was constructed following the methods described in Agrawal and Heady (1972), Beneke and Winterboer (1973), and Heady and Candler (1973). A single structural model was developed with twelve scenarios for accomplishment of the study objective. Waterfowl hunting activities were integrated in the structure of one of the twelve scenarios. The goal of the model was to maximize net returns (over variable costs) subject to the constraints of fixed resources. The model was composed of a series of equations stated as linear inequalities. The quantity of resources employed was assumed to be less than or equal to the amount available. Production was assumed to be greater than or equal to zero.

The scenarios were designated by the soil region, subregion, and farm size (e.g., REG21LG means Soil Region 2, Subregion 1, large farm) (Chamberlain 1984). Coefficients for all production activities changed on each model according to the budget. The basic structural model (with hunting) was:

$$\begin{aligned} \text{Maximize } Z &= \sum_{j=1}^n c_j x_j \\ \text{Subject to } \sum_{j=1}^n a_{ij} x_j &\leq b_i \\ x_j &\geq 0 \end{aligned}$$

where:

i = 1,2,...,m; and j = 1,2,...,n

Z is the total net revenue (above variable costs);

C_j is the net revenue (above variable costs) from activity j, in dollars/acre, or in dollars/unit of hunting;

X_j are crop, hunting, cash transfer, and cash borrowing activities;

a_1 is a vector of total land requirements;

a_2 is a vector of irrigated land requirements;

a_3 is a vector of playa land requirements;

a_i are vectors of irrigation water requirements for each month, where month = 1,2,...,12;

a_i are vectors of labor requirements for each month, where month = 1,2,...,12;

a_i are vectors of capital requirements for each month, where month = 1,2,...,12;

a_{40} is the ending balance for cash transfer or borrowing from the 12th period to the end period;

b_1 is a resource constraint for total land;

b_2 is a resource constraint for irrigable land;

b_3 is a resource constraint for playa land;

b_i are resource constraints for irrigation water for each month, where month = 1,2,...,12;

b_i are resource constraints for labor for each month, where month = 1,2,...,12;

b_i are resource constraints for capital for each month, where month = 1,2,...,12;

Upper bounds were used for the credit limit in each month (CRDTLIMTi). In addition, a system of fixed and upper bounds were used to segregate the hunting activities for separate repetitions of the basic model. The parametric model was basically the same with the addition of a negative one or positive one in the change column or the right hand side constraints for the resource being varied in each month (see Beneke and Winterboer 1973:124-129).

Results and Discussion

Results If No Playas Exist

The same model structure was used with twelve scenarios integrating the major crop activities on the High Plains. The crops chosen by the linear programming model as those maximizing gross margin were dependent on the subregion. When the model was run under the assumption that the playas did not exist, all land was considered available for cultivation. The transition from grain crops to fiber production was evident for those subregions located further south in the 19-county study area (Table 1). The expected transition from irrigated to dryland production also was confirmed. The ratio of irrigated to dryland production shifted in each subregion and between farm sizes within subregions.

Grain sorghum did not enter the farm plan as either a dryland or irrigated crop in any subregion or farm size. Irrigated wheat

also was excluded from all optimal crop mixes. Dryland wheat was included in both the large and small farm operation in Subregion I (REG21LG and REG21SM) but was included in only the large farm operations for other subregions. The only subregion in which sprinkler-irrigated cotton was chosen over furrow-irrigated cotton was the northern most in the Texas High Plains. Furrow-irrigated corn was included in only one farm size in one subregion, REG32LG. The most profitable subregion and farm size was REG23LG where the gross margin was \$59,436.32. The optimal crop mix was 691.49 acres of wheat, 222.94 acres of furrow-irrigated cotton, and 396.57 acres of sprinkler-irrigated corn.

The only subregion farms to exclude all irrigated crops from the farm plan were REG46-LG&SM. There, the crops on the large typical farm were dryland cotton and wheat and the small farm produced only dryland cotton. The most profitable small farm operation occurred in REG32SM where the gross margin was \$11,044.25.

Results If Playas Exist But Are Not Used

The second stage in the model comparisons was based on the existence of playas lacking any positive management for crops or wildlife. The playas were assumed to reduce the available total land per farm but not the number of irrigable acres.

No general shift occurred in the crops grown (Table 2). Some slight shifts were noted from dryland to irrigated crops. The amount of land used for dryland crop production was not binding. Only in REG46-LG&SM did the model consistently choose dryland crops for 100% of the crops grown. However, the model would have allotted more production of irrigated crops if the acreage of irrigated land had not been binding for small farms in all but the last subregion. Corn dropped out of the models as a viable part of the crop pattern in REG32SM and all other subregions to the south. No corn budgets were available for the REG46-LG&SM farms because corn is not a feasible crop in that subregion.

The maximum gross margin was maintained by REG23LG with \$58,097.65 resulting from production of 635.55 acres of dryland wheat, 216.08 acres of furrow-irrigated cotton and 408.35 acres of sprinkler-irrigated corn.

Results If Hunting Activities Are Integrated

The REG21LG typical farm was used for integration of waterfowl-hunting activities into the LP model. Integration into all farm models was impossible because of limited information on costs and revenues of operating hunting activities. Integration for all subregions and sizes would have required creation of 99 additional hunting activity budgets that matched operational

constraints of farm size, potential hunter revenue, and lessor costs.

All nine hunting activities developed by Chamberlain (1984) were included simultaneously for the first LP trials. The constraint for LANDPLY was set to equality rather than functioning as a maximum. The result was a combination of day hunting stages, neither at the level of operation budgeted. The model integrated 0.42 units of Stage-1 day hunting with 0.58 units of Stage-2 day hunting. The crops chosen by the model included 759.77 acres of dryland wheat, 249.23 acres of sprinkler-irrigated cotton, and 264.63 acres of sprinkler-irrigated corn. Labor was binding in March and December. The integration of partial units of two or more hunting levels was considered unacceptable because no data were available to indicate how such a mixture of lease types or stages would operate, or what costs would be appropriate.

Therefore, the model was amended to integrate each hunting activity separately by use of bounds. The LANDPLY equality constraint was maintained. Eight of the separate models produced feasible and optimal solutions. However, the model containing Stage 2 of day hunting proved infeasible. Labor was binding and the model could not bring the full 31.37 acres of LANDPLY into the farm plan. Therefore, the equality constraint was changed to a maximum. The model was altered by using bounds that added only one hunting

activity at any one time. (A copy of the program and input data files are included in a computer tape provided to the contract agency.)

The models containing all nine hunting activities were run again (Tables 3-5). The Stage-2 level of operation produced the most profitable solution for all three types of hunting leases. However, the Stage-2 day hunting activity was included in the farm plan at less than unit level. Labor was binding in March and December. Only 0.67 units of Stage-2 hunting was included using 20.99 acres of LANDPLY.

The amount of irrigated corn was increased in both Stage-1 and -2 activity levels for day hunting. Even though the model was constrained from including a full unit of Stage-2 day hunting, the model increased sprinkler-irrigated corn from 269.09 acres (under the assumption of full farming with no playas present) to 302.51 acres (in the model with day-hunting Stage 2). In effect, corn became a more valuable crop with hunting. The waste corn was an input creating a supplemental activity that increased the farm gross margin. Fewer acres of irrigated cotton were produced and dryland wheat increased.

No such difficulty was experienced with the other eight hunting models. All included hunting and increased revenue. Addition of

season leases (Stage 2) reduced by less than one acre the amount of irrigated corn produced. The crop management pattern was altered only by a 21.5-acre decrease in dryland wheat production (if the original model without playas is compared to the current model). Yearly leases had no affect on the crop-management choices made by the model. None of the resource constraints were binding when the eight hunting activities were added. The gross margin was slightly increased when Stage-1 yearly hunting was included in the farm plan (compared to Stage 0).

Post Optimization Analysis

The model for REG21LG, including all nine hunting activities, was tested further to define the range over which the resource constraints would be binding. Labor was increased by 174 hours per month in a parametric program increasing the labor resource to a maximum of 1,390 hours per month (i.e., five additional man-years distributed evenly throughout the year). The gross margin increased at each step to a maximum of \$75,978. At that level, labor was no longer binding but all three land constraints (TOTLAND, LANDIRR, and LANDPLY) and DUCKFOOD were binding. The optimal-activity selection at each stage was altered; dryland wheat decreased as irrigated cotton and irrigated corn increased up to the point where Stage-2 day hunting was included as a full unit. Stage-2 day hunting

occurred as an integer activity when labor increased from 694 to 868 hours per month. The gross margin increased at that step from \$65,891 to \$72,855. Dryland wheat was included in the farm plan at 434.03 acres, sprinkler-irrigated cotton at 456.26 acres, and sprinkler-irrigated corn at 383.33 acres. March and November labor still were binding the model at that step.

When labor again was increased (to 1042 hours per month), the gross margin increased to \$75,950 and the crop mix was shifted. Dryland wheat decreased to 362.22 acres, sprinkler-irrigated cotton increased to 630.26 acres, and sprinkler-irrigated corn decreased to 281.15 acres. Stage-2 day hunting was retained at the unit level. November labor was binding in addition to LANDPLY. DUCKFOOD was 1,776.56 kg on 281.15 acres of corn.

When labor was increased again to 1,390 hours per month, the resource no longer constrained the model. Gross revenue increased marginally to \$75,978. At that level, wheat was unchanged but irrigated cotton increased at the expense of irrigated corn. Sprinkler-irrigated cotton increased to 642.32 acres and sprinkler-irrigated corn decreased to 269.08 acres.

The range analysis executed on the last model indicated that all three land-resource types, capital in all months except November, and DUCKFOOD were included at the limiting level. Dryland

wheat included in the farm plan would drop out at the upper limit of the marginal value product range for TOTLAND. The shadow price or marginal value product of total land was \$20.96. That price was relevant from 942.78 to 1,400.75 acres. Each acre added from 1,305 to 1,400 would add \$20.96 to the value of the program. Each acre reduced from 1,305 to 942 would decrease the value of the program by \$20.96.

The range analysis for LANDPLY indicated that the shadow price was \$605.89 for each acre. The range was relevant from 30.97 to 39.24 acres. The model indicated a sensitivity to a very narrow range. Each unit decrease from 31.37 to 30.97 would reduce the value of the program by \$605, while each addition from 31.37 to 39.24 would increase the value by \$605.

A similar parametric program tested the range of irrigation water. The water available monthly was reduced in 1,000 acre-inch increments from 16,909 to zero acre inches. The farm plan was unchanged by the reduction in available irrigation water until the amount was lowered to 1609 acre-inches. At that level, the gross margin dropped to \$53,563 from \$58,155. Dryland wheat increased from 759.76 to 922.83 acres, irrigated cotton decreased from 249.23 to 149.67 acres, and irrigated corn dropped from 264.63 acres to 187.09 acres. Furrow-irrigated corn entered the model at that level with 14.03 acres. Waterfowl hunting was split throughout the model

as long as any water was available. However, at the same point of departure, the split shifted away from Stage 1 and toward Stage-2 day hunting. At no time did seasonal or yearly leases enter the model. When available water was reduced further (to 609 acre-inches per month), dryland wheat predominated with 1,140 acres. Only 56.65 acres of sprinkler-irrigated cotton remained in the model along with 70.81 acres of sprinkler-irrigated corn and 5.31 acres of furrow-irrigated corn. The hunting activities were split to include largely Stage-1 day hunting with lesser amounts of Stages 0 and 2.

When irrigation water was removed from the model, waterfowl hunting shifted to day hunting at Stage 0. The crop program was completely converted to dryland wheat. The range analysis indicated all forms of land, as well as water in June, July and October were binding. The shadow price for total land was relatively unchanged from that existing when labor was the parametrically-treated resource. The marginal value product for TOTLAND was \$20.40, and the range of the estimate was significant from 214.06 to 1,392.00 acres. From 1,305.00 to 214.00 acres, each acre reduction would decrease the value of the program by \$20.40 and from 1,305.00 to 1,392.55 acres, each acre added increased the value of the program by a like amount. Labor in September and capital borrowing between June and July were the limiting processes at the ends of the range.

Conclusions

The results of the LP model analysis indicate that waterfowl hunting, regardless of the farm program, can supplement farm income on the Texas High Plains. Shifts in resource availability directly affected the level at which hunting contributed. Hence, even in the extreme case of no irrigation, the model included unenhanced day hunting in the farm plan. The implications of this result must be given a hard look. The amount of available water in playas, if all irrigated cropping was excluded, probably would be marginal even in years with higher than normal rainfall and lowered evaporation rates.

The effect of concentrated day hunting on an area with no corn and extremely limited playa water could be disasterous. Reasons for this include: 1) a lowered carrying capacity for waterfowl, and 2) human-disturbance impacts. The only food available to waterfowl under the worst case scenario would be that naturally occurring in the playas. If all farms in the region were converted to such a regime, the regional carrying capacity would be lowered to the point where numbers of wintering waterfowl also would be reduced greatly. A study of human disturbances on the presence and behavior of waterfowl (including mallard, teal, and wigeon) indicated an extreme sensitivity of the birds to water-based recreation, especially boating. Because boating and hunting produce a high noise level

similar results would be expected in the latter case.

Distributional changes ranging from aberrations in feeding and roosting to complete abandonment of playas could result as the intensity of human activity increased (Tuite et al. 1983).

If the scenario above was improved, the potential of a mutually beneficial arrangement could increase. Additional water in playas was considered the only overt waterfowl habitat additive for purposes of the budgets and LP models. No other habitat restraints were used (with the exception of a minimum corn requirement) because empirical data proving a definite crop-waterfowl link were lacking. Obenberger (1982) and Guthery et al. (1984) indicated that the amount of surface water in playas was the habitat variable having the greatest single impact on the presence or absence of wintering waterfowl. Some positive crop relationships were indicated in several of the regressions attempted by those authors. However, the relationships may be spurious as irrigation was used extensively in the areas they investigated. Irrigation runoff accumulating in playas could have produced similar results, thus superficially linking waterfowl numbers to nearby crop patterns when in fact the real relationship was with the amount of water applied to the crops.

Pumping water for enhancement of waterfowl habitat is good business if fee-lease hunting in some form is integrated into the model. The LP models support the assumption that quality of hunting

over quantity is profitable. The continued effort by the LP model to integrate Stage-2 day hunting into the farm plan indicates that pumping water for waterfowl is profitable unless water available for irrigation decreases dramatically. Of course, the model does not account for potential increases in energy prices, a factor that could change the entire picture. A representative from the Sportsman's Club of America indicated that they were paying \$2 to \$4 per acre-foot for water pumped on rice fields until 1982 when the price went to \$25 per acre-foot. Even at \$25, pumping water for waterfowl still could be profitable. (The LP model price for water was \$20.16 per acre-foot).

More research may determine other links between farm resources and the presence or absence of waterfowl. Until specific relationships between waterfowl numbers and crop patterns and crop densities are established, water will remain the most reliable factor for economic purposes. Transfer rows can establish dependent relationships in LP models so that truly supplementary activities will be evaluated properly. Making waterfowl (or other wildlife) management concessions act competitively in LP models places wildlife resources in a truly difficult situation. The optimal solution will be extreme if the models are not constituted properly with realistic quarterly (if not monthly) resource constraints. If crop alterations favoring wildlife habitat are assigned too high a price, the models may include the alteration whether feasible in real life or not.

Every effort was made for the LP model tested here to conform with realistic situations. This effort included using hunting budgets weighted heavily on the costs of operation (Chamberlain 1984). A conservative approach was deemed most reasonable. If waterfowl are assisted by supplemental water during periods of low rainfall, and maintained with minimum food, both man and waterfowl could benefit. All things are, of course, relative. The budgets assumed an established hunting situation (i.e., existing demand for recreation), not one in which a functional market was lacking. If marketing costs were internalized for several years while the area became recognized for its hunting opportunity, the initial costs of operation could be greatly increased because the habitat would be augmented without a direct cash return. However, long-term benefits for both waterfowl and land managers could be realized if conservative but constructive decisions for resource allocations were made as described in this study. There is no reason why private funds cannot provide public benefits under the profit motive.

Table 1. Gross margins and optimal crop selections generated by the MPS-360 linear programming models for the twelve typical farms in the six subregions of the Texas High Plains 19-county study area (model assumes no playas exist, 1984).

ACTIVITY	REG21LG	REG21SM	REG23LG	REG23SM	REG32LG	REG32SM	REG34LG	REG34SM	REG35LG	REG35SM	REG46LG	REG46SM
GROSS MARGIN	44703.51	7854.07	59436.32	9652.76	46689.09	11044.25	35705.70	10100.59	34422.43	8460.38	27213.21	7355.10
TOTLAND (Limit)	1305.00	177.95	1311.00	160.99	1148.00	184.99	1137.99	173.00	1231.61	195.94	1289.86	188.98
LANDDRY	738.78	61.84	691.49	74.03	725.99	53.33	1050.38	67.99	852.60	109.68	1289.86	188.98
(z)	(56.61)	(34.75)	(52.75)	(45.98)	(63.24)	(28.83)	(92.30)	(39.30)	(69.23)	(55.98)	(100.00)	(100.00)
CT				74.03		53.33	347.35	67.99		109.68	411.07	188.98
GS	%			45.98		28.83	30.52	39.30		55.98	31.87	100.00
WT												
	738.78	61.84	691.49		725.99		703.03		852.60		878.79	
	56.61	34.75	52.75		63.24		61.78		69.23		68.13	
LANDIRR (Limit)	911.41	116.11	808.78	86.96	842.21	131.66	722.13	105.01	548.92	86.26	662.93	96.67
	566.22	116.11	619.51	86.96	422.01	131.66	87.61	105.01	379.01	86.26	0.00	0.00
(z)	(43.39)	(65.25)	(47.25)	(54.02)	(36.76)	(71.17)	(7.70)	(60.70)	(30.77)	(44.02)	(0.00)	(0.00)
ICTS		297.14	71.09									
	%	22.77	39.95									
ICTF				222.94	30.28	334.99	131.66	87.61	105.01	379.01	86.26	
IGSS	%			17.01	18.81	29.18	71.17	7.70	60.70	30.77	44.02	
IGSF	%											
IWTS	%											
IWTF	%											
ICNS		269.09	45.02	396.57	56.68							
	%	20.62	25.30	30.25	35.21							
ICNF	%					87.02						
						7.58						

Table 2. Gross margins and optimal crop selections generated by the MPS-360 linear programming models for the twelve typical farms in the six subregions of the Texas High Plains 19-county study area (model assumes the existence of playas that are not farmed or grazed).

ACTIVITY	REG21LG	REG21SM	REG23LG	REG23SM	REG32LG	REG32SM	REG34LG	REG34SM	REG35LG	REG35SM	REG46LG	REG46SM
GROSS MARGIN	44045.67	7511.30	58097.65	8467.95	46282.79	10802.82	35313.66	9516.24	34300.70	8343.53	27177.77	7306.45
TOTLAND (Limit)	1273.63	162.26	1259.98	135.48	1132.01	176.99	1116.81	162.41	1224.63	192.45	1287.37	187.73
LANDDRY (%)	1273.63	162.26	1259.98	135.48	1132.01	176.99	1116.81	162.41	1224.63	192.45	1287.37	187.73
WT	706.90	46.15	635.55	48.52	710.00	45.33	1029.20	57.40	845.62	106.19	1287.37	187.73
GS (%)	(55.50)	(28.44)	(50.44)	(35.81)	(62.72)	(25.61)	(92.16)	(35.34)	(69.05)	(55.18)	(100.00)	(100.00)
ICTS (%)	296.43	71.85		48.52		45.33	347.35	57.40		106.19	411.07	187.73
ICTF (%)	23.27	44.28		35.81		25.61	31.10	35.34		55.18	31.93	100.00
IGSS (%)												
IGSF (%)												
IWTS (%)												
IWTF (%)												
ICNS (%)	270.31	44.26	408.35	50.04								
ICNF (%)	21.22	27.28	32.41	36.94		87.02						
						7.69						
LANDPLY	31.37	15.69	51.02	25.51	15.99	8.00	21.18	10.59	6.98	3.49	2.49	1.25

Table 3. Gross margins and optimal crop selections generated by the MPS-360 linear programming models for Subregion I, large typical farm, integrating day-hunting activities (1984).

	Total (All hunt) REG21LG	BNDDAY0	BNDDAY1	BNDDAY2
Gross Margin (C)	58155.22	51444.52	53676.56	55654.68
TOTLAND (Limit) (Amount used)	1305.00 1305.00	1305.00 1305.00	1305.00 1305.00	1305.00 1305.00
LANDPLY (Limit) (Amount used)	31.37 31.37	31.37 31.37	31.37 31.37	31.37 *20.99
LANDDRY (Amt. used)	759.77	726.52	719.02	756.04
CT				
GS				
WT	759.77	726.52	719.02	756.04
LANDIRR (Limit) (Amount used)	911.41 513.86	911.41 547.11	911.41 544.60	911.41 529.97
ICTS	249.23	282.00	283.04	225.46
ICTF				
IGSS				
IGSF				
IWTS				
IWTF				
ICNS	264.63	265.11	271.56	302.51
ICNF				
Hunting Type				
DAY0		1.00		
DAY1	*0.42		1.00	
DAY2	0.58			*0.67
BINDING	*LABOR12 LABOR3 LANDPLY	LABOR3	LABOR3	*LABOR12 LABOR3

Table 4. Gross margins and optimal crop selections generated by the MPS-360 linear programming models for Subregion I, large typical farm, integrating season-hunting activities (1984).

	BNDSEAO	BNDSEA1	BNDSEA2
Gross Margin (C)	47113.70	47814.68	49539.87
TOTLAND (Limit) (Amount used)	1305.00 1305.00	1305.00 1305.00	1305.00 1305.00
LANDPLY (Limit) (Amount used)	31.37 31.37	31.37 31.37	31.37 31.37
LANDDRY (Amt. used)	707.08	707.18	707.28
CT			
GS			
WT	707.08	707.18	707.28
LANDIRR (Limit) (Amount used)	911.41 566.55	911.41 566.45	911.41 566.35
ICTS	296.68	296.82	296.97
ICTF			
IGSS			
IGSF			
IWTS			
IWTF			
ICNS	269.87	269.62	269.38
ICNF			
 Hunting Type			
SEASON0	1.00		
SEASON1		1.00	
SEASON2			1.00
BINDING	LABOR3	LABOR3	LABOR3

Table 5. Gross margins and optimal crop selections generated by the MPS-360 linear programming models for Subregion I, large typical farm, integrating yearly-hunting activities (1984).

	BNDYRO	BNDYR1	BNDYR2
Gross Margin (C)	45892.49	46520.93	46520.93
TOTLAND (Limit) (Amount used)	1305.00 1305.00	1305.00 1305.00	1305.00 1305.00
LANDPLY (Limit) (Amount used)	31.37 31.37	31.37 31.37	31.37 31.37
LANDDRY (Amt. used)	706.93	706.93	706.93
CT			
GS			
WT	706.93	706.93	706.93
LANDIRR (Limit) (Amount used)	911.41 566.70	911.41 566.70	911.41 566.70
ICTS	296.47	296.47	296.47
ICTF			
IGSS			
IGSF			
IWTS			
IWTF			
ICNS	270.23	270.23	270.23
ICNF			
 Hunting Type			
YEAR0	1.00		
YEAR1		1.00	
YEAR2			1.00
BINDING	LABOR3	LABOR3	LABOR3

Literature Cited

Agrawal, R. C. and E. O. Heady. 1972. Operations research methods for agricultural decisions. Iowa State Univ. Press, Ames, Iowa. 303pp.

Arnon, I. 1972. Agricultural development in dry regions. Pages 550-598 in Crop production in dry regions. Barnes and Nobles, N.Y.

Baldassarre, G. A., R. J. Whyte, E. E. Quinlan, E. G. Bolen. 1983. Dynamics and quality of waste corn available to postbreeding waterfowl in Texas. Wildl. Soc. Bull. 11:25-31.

Beneke, R. R. and R. Winterboer. 1973. Linear programming applications to agriculture. Iowa State Univ. Press, Ames, Iowa. 244pp.

Chamberlain, P.A. 1984. Waterfowl and agriculture--an assessment of wintering waterfowl management and land-use economics on the Texas High Plains. Ph.D. Dissertation. Texas Tech Univ., Lubbock. 547pp.

Cross Section. 1983. Dikes increase yields. The Cross Section. High Plains Underground Water Conserv. Dist. 1. Lubbock, Tex. 29(1):4.

Guthery, F. S. and F. C. Bryant. 1982. Status of playas in the southern Great Plains. Wildl. Soc. Bull. 10:309-317.

_____, S. M. Obenberger, F. A. Stormer. 1984. Predictors of site use by ducks on the Texas High Plains. Wildl. Soc. Bull. 12:35-40.

Heady, E. O. and W. Candler. 1973. Linear programming methods. 7th Ed. Iowa State Univ. Press, Ames, Iowa. 597pp.

Lacewell, R. D. 1976. Impact of energy cost on food and fiber production. Pages 57-76 in Proceedings of the TAMU Centennial Year water for Texas conference, Texas A&M Univ., College Station. March 25-26, 1976. 138pp.

Obenberger, S. M. 1982. Numerical response of wintering waterfowl to macrohabitat in the southern High Plains of Texas. M.S. Thesis. Texas Tech Univ., Lubbock. 43pp.

Powers, J. E. 1979. Planning for an optimal mix of agricultural and wildlife land use. *J. Wildl. Manage.* 43:493-502.

Texas Department of Water Resources. 1980. Playa lake monitoring for the Llano Estacado total water management study: Texas, Oklahoma, New Mexico, Colorado, and Kansas. Austin, Tex. Rep. LP-114. 18pp.

Tuite, C. H., M. Owen, and D. Paynter. 1983. Interaction between wildfowl and recreation at Llangorse Lake and Talybont Reservoir South Wales. *Wildfowl.* 34:48-63.

White, G. F. 1966. The worlds arid areas. Pages 15-30 in E. S. Hills. *Arid lands, a geographical appraisal.* Methuen and Co., Ltd., London.

APPENDIX A
LINEAR PROGRAMMING MATERIALS

**LOWER BOUND
UPPER BOUND**

F F F F F F F F F F F F

EXECUTOR. MPS/360 V2-M11

SUMMARY OF MATRIX

SYMBOL	RANGE	COUNT (INCL.RHS)
Z	LESS THAN .C00001	
Y	.000001 THRU .C00009	
X	.000010 .C00099	
W	.000100 .C00999	
V	.001000 .009999	
U	.010000 .C99999 12	
T	.100000 .999999 62	
I	1.000000 1.C00000 54	
A	1.000001 10.C00000 57	
B	10.000001 100.C00000 131	
C	100.000001 1,000.000000 70	
D	1,000.000001 10,000.C00000 27	
E	10,000.000001 100,000.C00000 21	
F	100,000.000001 1,000,000.C00000	
G	GREATER THAN 1,000,000.C00000	

```

0001      PROGRAM
0002      INITIALZ
0065      MOVE(XDATA,'REG21LG')
0066      MOVE(XPBNM,'PBFILE')
0067      CONVERT('SUMMARY')
0068      BCDOUT
0069      SETUP('MAX','BOUNDS','BNDOCRDT')
0070      MOVE(XRHS,'B')
0071      MOVE(XOBJ,'C')
0072      PICTURE
0073      PRIMAL
0074      SAVE
0075      SOLUTION
0076      CHECK
0077      SETUP('MAX','BOUNDS','BNDDAY0')
0078      RESTORE
0079      PICTURE
0080      PRIMAL
0081      SAVE
0082      SOLUTION
0083      CHECK
0084      SETUP('MAX','BOUNDS','BNDAY1')
0085      RESTORE
0086      PICTURE
0087      PRIMAL
0088      SAVE
0089      SOLUTION
0090      CHECK
0091      SETUP('MAX','BOUNDS','BNDAY2')
0092      RESTORE
0093      PICTURE
0094      PRIMAL
0095      SAVE
0096      SOLUTION
0097      CHECK
0098      SETUP('MAX','BOUNDS','BNDSEAO')
0099      RESTORE
0100      PICTURE
0101      PRIMAL
0102      SAVE
0103      SOLUTION
0104      CHECK
0105      SETUP('MAX','BOUNDS','BNDSEAL')
0106      RESTORE
0107      PICTURE
0108      PRIMAL
0109      SAVE
0110      SCLUTION
0111      CHECK
0112      SETUP('MAX','BOUNDS','BNCSEAR')
0113      RESTORE
0114      PICTURE
0115      PRIMAL
0116      SAVE

```

CONTROL PROGRAM COMPILER - MPS/360 V2-M11

0117	SCLUTION
0118	CHECK
0119	SETUP('MAX','BOUNDS','BNDYR0')
0120	RESTORE
0121	PICTURE
0122	PRIMAL
0123	SAVE
0124	SCLUTION
0125	CHECK
0126	SETUP('MAX','BOUNDS','BNDYR1')
0127	RESTORE
0128	PICTURE
0129	PRIMAL
0130	SAVE
0131	SCLUTION
0132	CHECK
0133	SETUP('MAX','BOUNDS','BNDYR2')
0134	RESTORE
0135	PICTURE
0136	PRIMAL
0137	SOLUTION
0138	CHECK
0139	EXIT
0140	PENC

NAME REG21LG

N C									
L TOTLAND									
L LANDIRR									
L LANDPLY									
L H2OIRR1									
L H2OIRR2									
L H2OIRR3									
L H2OIRR4									
L H2OIRR5									
L H2OIRR6									
L H2OIRR7									
L H2OIRR8									
L H2OIRR9									
L H2OIRR10									
L H2OIRR11									
L H2OIRR12									
L LABOR1									
L LABOR2									
L LABCR3									
L LABOR4									
L LABCR5									
L LABCR6									
L LABOR7									
L LABCR8									
L LABOR9									
L LABOR10									
L LABCR11									
L LABOR12									
L CAPTL1									
L CAPTL2									
L CAPTL3									
L CAPTL4									
L CAPTL5									
L CAPTL6									
L CAPTL7									
L CAPTL8									
L CAPTL9									
L CAPTL10									
L CAPTL11									
L CAPTL12									
L ENDBAL									
L DUCKFC00									

COLUMNS

CT21 C	16.50000	TOTLAND	1.00000	IGSF21 CAPTL2	2.42000	CAPTL3	47.31000
CT21 LABOR2	.56700	LABOR3	1.20800	IGSF21 CAPTL4	2.26000	CAPTL5	22.96000
CT21 LABOR5	1.18900	LABOR6	.46300	IGSF21 CAPTL6	12.64000	CAPTL7	20.64000
CT21 LABOR12	.86900	CAPTL1	- 115.36000	IGSF21 CAPTL8	12.64000	CAPTL10	24.57000
CT21 CAPTL2	6.59000	CAPTL3	18.22000	IGSF21 CAPTL11	5.64000	CAPTL12	- 187.66000
CT21 CAPTL5	22.20000	CAPTL6	5.38000	IWTS21 C	- 22.19000	TOTLAND	1.00000
CT21 CAPTL11	30.72000	CAPTL12	10.10000	IWTS21 LANDIRR	1.00000	H2OIRR3	2.00000
GS21 C	16.76000	TOTLAND	1.00000	IWTS21 H2OIRR4	4.00000	H2CIRR5	4.00000
GS21 LABOR2	.13200	LABOR4	.34000	IWTS21 H2OIRR9	3.00000	H2OIRR11	2.00000
				IWTS21 H2OIRR12	2.00000	LABOR3	.20000
				IWTS21 LABOR4	.40000	LABOR5	.40000
				IWTS21 LABOR7	.20800	LABOR8	.77600
				IWTS21 LABOR9	.30000	LABOR11	.20000

SEASON2	CAPTL10	197.93000	CAPTL11	110.43000
SEASON2	CAPTL12	81.75000	CUCKFOOD	39639.64000
YEAR0	C	1790.00000	TOTLAND	31.37000
YEAR0	LANDPLY	31.37000	LABOR1	2.000CO
YEAR0	LABCR9	4.00000	LABOR10	2.000CO
YEAR0	LABOR11	4.00000	LABOR12	2.00000
YEAR0	CAPTL1	18.00000	CAPTL8	- 2000.000C0
YEAR0	CAPTL9	28.00000	CAPTL10	118.00000
YEAR0	CAPTL11	28.00000	CAPTL12	18.00000
YEAR1	C	240C.00000	TOTLAND	31.370C0
YEAR1	LANDPLY	31.37000	H2CIRR1	413.460C0
YEAR1	H2OIRR11	467.41000	H2CIRR12	446.080C0
YEAR1	LABOR1	22.67000	LABOR9	4.00000
YEAR1	LABOR10	2.00000	LABOR11	27.37000
YEAR1	LABOR12	24.30000	CAPTL1	18.000C0
YEAR1	CAPTL8	- 261C.00000	CAPTL9	28.00000
YEAR1	CAPTL10	118.C0C00	CAPTL11	28.00000
YEAR1	CAPTL12	18.00000		
YEAR2	C	240C.00000	TOTLAND	31.370C0
YEAR2	LANDPLY	31.37000	H2OIRR1	413.460C0
YEAR2	H2OIRR11	467.41000	H2OIRR12	446.080C0
YEAR2	LABOR1	22.67000	LABOR9	4.00000
YEAR2	LABOR10	2.00000	LABOR11	27.370C0
YEAR2	LABOR12	24.30000	CAPTL1	18.00000
YEAR2	CAPTL8	- 261C.00000	CAPTL9	28.00000
YEAR2	CAPTL10	118.00000	CAPTL11	28.00000
YEAR2	CAPTL12	18.0C000	CUCKFCOD	39639.64000
CTR12	CAPTL1	1.00000	CAPTL2	- 1.000C0
CTR23	CAPTL2	1.00000	CAPTL3	- 1.000CO
CTR34	CAPTL3	1.0CC0C	CAPTL4	- 1.000CO
CTR45	CAPTL4	1.00000	CAPTL5	- 1.000CO
CTR56	CAPTL5	1.00000	CAPTL6	- 1.00000
CTR67	CAPTL6	1.CC000	CAPTL7	- 1.00000
CTR78	CAPTL7	1.00000	CAPTL8	- 1.00000
CTR89	CAPTL8	1.0C00C	CAPTL9	- 1.00000
CTR910	CAPTL9	1.00000	CAPTL10	- 1.000CO
CTR1011	CAPTL10	1.00000	CAPTL11	- 1.000C0
CTR1112	CAPTL11	1.0CC0C	CAPTL12	- 1.000CO
CTR12EB	CAPTL12	1.00000	ENDBAL	- 1.000CO
CBR12	C	- .C150C	CAPTL1	- 1.00000
CBR12	CAPTL2	1.01500		
CSR23	C	- .01500	CAPTL2	- 1.00000
CBR23	CAPTL3	1.C150C		
CSR34	C	- .01500	CAPTL3	- 1.000CO
CBR34	CAPTL4	1.C150C		
CBR45	C	- .C1500	CAPTL4	- 1.000CO
CBR45	CAPTL5	1.01500		
CBR56	C	- .C1500	CAPTL5	- 1.000CO
CBR56	CAPTL6	1.C1500		
CBR67	C	- .C150C	CAPTL6	- 1.00000
CBR67	CAPTL7	1.C1500		
CBR78	C	- .01500	CAPTL7	- 1.000CO
CBR78	CAPTL8	1.01500		
CBR89	C	- .C1500	CAPTL8	- 1.000CO

CBR89	CAPTL9	1.C1500		
CBR910	C	.01500	CAPTL9	-
CBR91C	CAPTL10	1.C1500	CAPTL10	-
CBR1011	C	.01500	CAPTL11	-
CBR1011	CAPTL11	1.C1500	CAPTL12	-
CBR1112	C	.01500	CAPTL12	-
CBR1112	CAPTL12	1.01500		
CBR12EB	C	.01500		
CBR12EE	ENDBAL	1.01500		
RHS				
B	TOTLAND	13C5.CC00C	LANDIRR	911.41000
B	LANDPLY	31.37000	H2CIRR1	16609.00000
B	H2OIRR2	166C5.00000	H2CIRR3	16609.00000
B	H2OIRR4	166C5.CC000	H2OIRR5	16609.30000
B	H2OIRR6	166C5.00000	H2OIRR7	16609.00000
B	H2OIRR8	166C5.00000	H2OIRR9	16609.00000
B	H2OIRR10	166C5.00000	H2CIRR11	16609.00000
B	H2OIRR12	166C5.00000	LABOR1	520.00000
B	LABOR2	52C.CCC0C	LABOR3	520.00000
B	LABCR4	52C.00000	LABOR5	520.CC000
B	LABOR6	52C.00000	LABORT	520.00000
B	LABOR8	52C.00000	LABOR9	520.00000
B	LABCR10	52C.00000	LABOR11	520.00000
B	LABOR12	52C.00000		
BCUNCS				
UP	BNDOCRTD	CBR12	194632.0000	
UP	BNDOCRTD	CBR23	194632.C00C	
UP	BNDOCRTD	CBR34	194632.0000	
UP	BNDOCRTD	CBR45	194632.0000	
UP	BNDOCRTD	CBR56	194632.C000	
UP	BNDOCRTD	CBR67	194632.CC0G	
UP	BNDOCRTD	CBR78	194632.0000	
UP	BNDOCRTD	CBR89	194632.C000	
UP	BNDOCRTD	CBR910	194632.0000	
UP	BNDOCRTD	CBR1011	194632.0000	
UP	BNDOCRTD	CBR1112	194632.C000	
UP	BNDOCRTD	CBR12EB	194632.0000	
UP	BNDDAYO	DAYO	1.00000	
FX	BNDDAYO	DAY1	.	
FX	BNDDAYO	DAY2	.	
FX	BNDCAYO	SEASCN0	.	
FX	BNDCAYO	SEASCN1	.	
FX	BNDCAYO	SEASCN2	.	
FX	BNDCAYO	YEAR0	.	
FX	BNDCAYO	YEAR1	.	
FX	BNDCAYO	YEAR2	.	
UP	BNDDAYO	CBR12	194632.CC00	
UP	BNDDAYO	CBR23	194632.0C00	
UP	BNDDAYO	CBR34	194632.0000	
UP	BNDDAYO	CBR45	194632.0000	
UP	BNDDAYO	CBR56	194632.C000	
UP	BNDDAYO	CBR67	194632.0000	
UP	BNDDAYO	CBR78	194632.C00C	
UP	BNDDAYO	CBR89	194632.CC0C	

UP BNDDAY0	CBR910	194632.0000		
UP BNDCAY0	CBR1011	194632.0000		
UP BNDDAY0	CBR1112	194632.0000		
UP BNDCAY0	CBR12EB	194632.C000		
FX BNDDAY1	DAY0	.		
UP BNDDAY1	DAY1	1.00000		
FX BNDDAY1	DAY2	.		
FX BNDDAY1	SEASON0	.		
FX BNDCAY1	SEASON1	.		
FX BNDDAY1	SEASON2	.		
FX BNDDAY1	YEAR0	.		
FX BNDCAY1	YEAR1	.		
FX BNDDAY1	YEAR2	.		
UP BNDDAY1	CBR12	194632.CC00		
UP BNDDAY1	CBR23	194632.C000		
UP BNDDAY1	CBR34	194632.0000		
UP BNDCAY1	CBR45	194632.C000		
UP BNDDAY1	CBR56	194632.0000		
UP BNDCAY1	CBR67	194632.C000		
UP BNDCAY1	CBR78	194632.C000		
UP BNDDAY1	CBR89	194632.C000		
UP BNDCAY1	CBR910	194632.C000		
UP BNDDAY1	CBR1011	194632.C000		
UP BNDDAY1	CBR1112	194632.C000		
UP BNDCAY1	CBR12EB	194632.C00C		
FX BNDDAY2	DAY0	.		
FX BNDDAY2	DAY1	.		
UP BNDCAY2	DAY2	1.00000		
FX BNDDAY2	SEASON0	.		
FX BNDCAY2	SEASON1	.		
FX BNDDAY2	SEASCN2	.		
FX BNDDAY2	YEAR0	.		
FX BNDCAY2	YEAR1	.		
FX BNDDAY2	YEAR2	.		
UP BNDDAY2	CBR12	194632.CC00		
UP BNDDAY2	CBR23	194632.0000		
UP BNDDAY2	CBR34	194632.0000		
UP BNDDAY2	CBR45	194632.C000		
UP BNDDAY2	CBR56	194632.0000		
UP BNDDAY2	CBR67	194632.0000		
UP BNDCAY2	CBR78	194632.C000		
UP BNDCAY2	CBR89	194632.0000		
UP BNDDAY2	CBR910	194632.CC0C		
UP BNDCAY2	CBR1011	194632.0000		
UP BNDDAY2	CBR1112	194632.C000		
UP BNDCAY2	CBR12EB	194632.C00C		
FX BNDEAO	DAY0	.		
FX BNDEAO	DAY1	.		
FX BNDEAO	DAY2	.		
UP BNDEAO	SEASCN0	1.00000		
FX BNDEAO	SEASON1	.		
FX BNDEAO	SEASON2	.		
FX BNDEAO	YEAR0	.		
FX BNDEAO	YEAR1	.		
FX BNDEAO	YEAR2	.		
UP BNDEAO	CBR12	.		
UP BNDEAO	CBR23	194632.0000		
UP BNDEAO	CBR34	194632.CC0C		
UP BNDEAO	CBR45	194632.CC00		
UP BNDEAO	CBR56	194632.CC00		
UP BNDEAO	CBR67	194632.CC0C		
LP BNDEAO	CBR78	194632.0000		
UP BNDEAO	CBR89	194632.C00C		
UP BNDEAO	CBR910	194632.C000		
UP BNDEAO	CBR1011	194632.C000		
UP BNDEAO	CBR1112	194632.C000		
UP BNDEAO	CBR12EB	194632.C00C		
FX BNDEAO	DAY0	.		
FX BNDEAO	DAY1	.		
FX BNDEAO	DAY2	.		
UP BNDEAO	SEASCN0	1.00000		
FX BNDEAO	SEASON1	.		
FX BNDEAO	SEASON2	.		
FX BNDEAO	YEAR0	.		
FX BNDEAO	YEAR1	.		
FX BNDEAO	YEAR2	.		
UP BNDEAO	CBR12	.		
UP BNDEAO	CBR23	194632.0000		
UP BNDEAO	CBR34	194632.CC0C		
UP BNDEAO	CBR45	194632.CC00		
UP BNDEAO	CBR56	194632.CC00		
UP BNDEAO	CBR67	194632.CC0C		
LP BNDEAO	CBR78	194632.0000		
UP BNDEAO	CBR89	194632.C00C		
UP BNDEAO	CBR910	194632.C000		
UP BNDEAO	CBR1011	194632.C000		
UP BNDEAO	CBR1112	194632.C000		
UP BNDEAO	CBR12EB	194632.C00C		

UP	BNOSEA2	CBR12EB	194632.0000
FX	BNDYR0	DAY0	.
FX	BNDYRC	DAY1	.
FX	BNDYR0	DAY2	.
FX	BNDYR0	SEASOHO	.
FX	BNDYRC	SEASON1	.
FX	BNDYR0	SEASON2	.
UP	BNDYR0	YEAR0	1.00000
FX	BNDYRC	YEAR1	.
FX	BNDYRC	YEAR2	.
UP	BNDYRC	CBR12	194632.0000
UP	BNDYR0	CBR23	194632.0000
UP	BNDYR0	CBR34	194632.0000
UP	BNDYRC	CBR45	194632.0000
UP	BNDYR0	CBR56	194632.0000
UP	BNDYR0	CBR67	194632.0000
UP	BNDYRC	CBR78	194632.0000
UP	BNDYR0	CBR89	194632.0000
UP	BNDYRC	CBR910	194632.0000
UP	BNDYR0	CBR1011	194632.0000
UP	BNDYRC	CBR1112	194632.0000
UP	BNDYR0	CBR12EB	194632.0000
FX	BNDYR1	DAY0	.
FX	BNDYR1	DAY1	.
FX	BNDYR1	DAY2	.
FX	BNDYR1	SEASOHO	.
FX	BNDYR1	SEASON1	.
FX	BNDYR1	SEASON2	.
FX	BNDYR1	YEAR0	.
UP	BNDYR1	YEAR1	1.CCCOC
FX	BNDYR1	YEAR2	.
UP	BNDYR1	CBR12	194632.0000
UP	BNDYR1	CBR23	194632.0000
UP	BNDYR1	CBR34	194632.0000
UP	BNDYR1	CBR45	194632.0000
UP	BNDYR1	CBR56	194632.0000
UP	BNDYR1	CBR67	194632.0000
UP	BNDYR1	CBR78	194632.0000
UP	BNDYR1	CBR89	194632.0000
UP	BNDYR1	CBR910	194632.0000
UP	BNDYR1	CBR1011	194632.0000
UP	BNDYR1	CBR1112	194632.0000
LP	BNDYR1	CBR12EB	194632.0000
FX	BNDYR2	DAY0	.
FX	BNDYR2	DAY1	.
FX	BNDYR2	DAY2	.
FX	BNDYR2	SEASOHO	.
FX	BNDYR2	SEASON1	.
FX	BNDYR2	SEASON2	.
FX	BNDYR2	YEAR0	.
FX	BNDYR2	YEAR1	.
UP	BNDYR2	YEAR2	1.CCCOC
LP	BNDYR2	CBR12	194632.0000
LP	BNDYR2	CBR23	194632.0000

SECTION 1 - ROWS

NUMBER	...ROW...	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
1	C	BS	58155.21489	58155.21489-	NONE	NONE	1.00000
2	TOTLAND	UL	1305.00000	.	NONE	1305.00000	21.11097-
3	LANDIRR	BS	513.86408	397.54592	NONE	911.41000	.
4	LANDPLY	UL	31.37000	.	NONE	31.37000	233.34006-
5	H2CIRR1	BS	652.74510	15956.25490	NONE	16609.00000	.
6	H2CIRR2	BS	528.30695	16080.69305	NONE	16609.00000	.
7	H2CIRR3	BS	1481.97036	15127.02564	NONE	16609.00000	.
8	H2CIRR4	BS	2538.51932	14070.48068	NONE	16609.00000	.
9	H2CIRR5	BS	.	16609.00000	NONE	16609.00000	.
10	H2CIRR6	BS	2304.68809	14304.31191	NONE	16609.00000	.
11	H2CIRR7	BS	2117.05851	14491.94149	NONE	16609.00000	.
12	H2CIRR8	BS	1587.79388	15021.20612	NONE	16609.00000	.
13	H2CIRR9	BS	551.12320	16017.87680	NONE	16609.00000	.
14	H2CIRR10	BS	822.61733	15786.38267	NONE	16609.00000	.
15	H2CIRR11	BS	737.91802	15871.08198	NONE	16609.00000	.
16	H2CIRR12	BS	704.24354	15904.75646	NONE	16609.00000	.
17	LABOR1	BS	399.73808	120.26192	NONE	520.00000	.
18	LABOR2	BS	123.31312	386.68688	NONE	520.00000	.
19	LABOR3	UL	520.00000	.	NONE	520.00000	29.27188-
20	LABOR4	BS	323.54699	196.45301	NONE	520.00000	.
21	LABOR5	BS	436.68435	83.31565	NONE	520.00000	.
22	LABOR6	BS	215.76414	304.23586	NONE	520.00000	.
23	LABOR7	BS	436.61084	83.38516	NONE	520.00000	.
24	LABOR8	BS	158.77939	361.22061	NONE	520.00000	.
25	LABOR9	BS	378.95794	141.00206	NONE	520.00000	.
26	LABOR10	BS	119.78733	400.21267	NONE	520.00000	.
27	LABOR11	BS	515.90184	4.09816	NONE	520.00000	.
28	LABOR12	UL	520.00000	.	NONE	520.00000	15.50797-
29	CAPTL1	UL	.	.	NONE	.	.07042-
30	CAPTL2	UL	.	.	NONE	.	.07042-
31	CAPTL3	UL	.	.	NONE	.	.07042-
32	CAPTL4	UL	.	.	NONE	.	.07042-
33	CAPTL5	UL	.	.	NONE	.	.07042-
34	CAPTL6	UL	.	.	NONE	.	.07042-
35	CAPTL7	UL	.	.	NONE	.	.05460-
36	CAPTL8	UL	.	.	NONE	.	.03901-
37	CAPTL9	UL	.	.	NONE	.	.03022-
38	CAPTL10	UL	.	.	NONE	.	.01500-
39	CAPTL11	ES	39337.35979-	39337.35979	NONE	.	.
40	CAPTL12	UL	.	.	NONE	.	.
41	ENCBAL	BS	25087.58182-	25087.58182	NONE	.	.
42	LUCKFCCD	BS	16042.01216-	16042.01216	NONE	.	.

SECTION 2 - COLUMNS

NUMBER	COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT..	..UPPER LIMIT..	.REDUCED COST..
43	CT21	LL	.	16.5000	.	NONE	49.01354-
44	GS21	LL	.	16.7600C	.	NONE	6.23517-
45	WT21	BS	755.76592	20.70G00	.	NCNE	.
46	ICTS21	BS	249.23177	51.44000	.	NONE	.
47	IGSS21	LL	.	29.04000	.	NONE	6.19249-
48	IGSF21	LL	.	27.92000	.	NONE	36.47191-
49	IWTS21	LL	.	22.19000-	.	NONE	53.76855-
50	IWTF21	LL	.	42.97000-	.	NONE	66.32281-
51	ICNS21	BS	264.63231	54.8200C	.	NONE	.
52	ICNF21	LL	.	46.07000	.	NONE	24.67912-
53	CAY0	LL	.	7988.0000C	.	NCNE	1874.02496-
54	CAY1	BS	.42126	10014.65000	.	NONE	.
55	CAY2	BS	.57874	20712.61000	.	NCNE	.
56	SEASON0	LL	.	2977.30G00	.	NONE	4917.88357-
57	SEASON1	LL	.	3622.28000	.	NONE	4546.33686-
58	SEASCN2	LL	.	5273.0400C	.	NCNE	2799.03086-
59	YEAR0	LL	.	1790.00000	.	NONE	6148.99842-
60	YEAR1	LL	.	2400.00000	.	NONE	5861.02711-
61	YEAR2	LL	.	2400.00000C	.	NONE	5861.02711-
62	CTR12	BS	67896.98539	.	.	NONE	.
63	CTR23	BS	65825.85669	.	.	NCNE	.
64	CTR34	BS	45546.10276	.	.	NONE	.
65	CTR45	BS	23483.83152	.	.	NONE	.
66	CTR56	BS	9231.67876	.	.	NONE	.
67	CTR67	LL	.	.	.	NONE	.01582-
68	CTR78	LL	.	.	.	NONE	.01559-
69	CTR89	LL	.	.	.	NCNE	.00879-
70	CTR910	LL	.	.	.	NONE	.01522-
71	CTR1011	LL	.	.	.	NONE	.01500-
A	CTR1112	LL	.	.	.	NONE	.
73	CTR12EB	BS	250E7.58182	.	.	NONE	.
74	CBR12	LL	.	.01500-	.	194632.00000	.01606-
75	CBR23	LL	.	.01500-	.	194632.0000C	.01606-
76	CBR34	LL	.	.01500-	.	194632.00000	.01606-
77	CBR45	LL	.	.0150C-	.	194632.0000C	.01606-
78	CBR56	LL	.	.01500-	.	194632.0000C	.01606-
79	CBR67	BS	3230.15833	.01500-	.	194632.00000	.
80	CBR78	BS	17805.36553	.01500-	.	194632.0000C	.
81	CBR89	LL	.	.0150C-	.	194632.0000C	.00666-
82	CBR910	BS	17886.78819	.0150C-	.	194632.00000	.
83	CBR1011	BS	34775.90848	.0150C-	.	194632.0000C	.
84	CBR1112	LL	.	.01500-	.	194632.00000	.01500-
85	CBR12EB	LL	.	.0150C-	.	194632.0000C	.01500-

CHECK TIME = 0.02 MINS

ROW NAME	UPPER LIMIT	LOWER LIMIT	RCW ERROR
C	NONE	NONE	.
TOTLAND	1305.000000	NONE	.
LANDIRR	911.410000	NONE	.
LANDPLY	31.370000	NONE	.
H2OIRR1	16609.000000	NONE	.
H2OIRR2	16609.000000	NONE	.
H2CIRR3	16609.000000	NONE	.
H2OIRR4	16609.000000	NONE	.
H2CIRR5	16609.000000	NONE	.
H2GIRR6	16609.000000	NONE	.
H2CIRR7	16609.000000	NONE	.
H2CIRR8	16609.000000	NONE	.
H2CIRR9	16609.000000	NCNE	.
H2CIRR10	16609.000000	NONE	.
H2CIRR11	16609.000000	NONE	.
H2OIRR12	16609.000000	NONE	.
LABOR1	520.000000	NONE	.
LABOR2	520.000000	NONE	.
LABOR3	520.000000	NONE	.
LABOR4	520.000000	NCNE	.
LABOR5	520.000000	NONE	.
LABOR6	520.000000	NONE	.
LABOR7	520.000000	NONE	.
LABOR8	520.000000	NCNE	.
LABOR9	520.000000	NONE	.
LABOR10	520.000000	NONE	.
LABOR11	520.000000	NONE	.
LABOR12	520.000000	NONE	.
CAPTL1	.	NCNE	.
CAPTL2	.	NONE	.
CAPTL3	.	NCNE	.
CAPTL4	.	NCNE	.
CAPTL5	.	NONE	.
CAPTL6	.	NCNE	.
CAPTL7	.	NCNE	.
CAPTL8	.	NONE	.
CAPTL9	.	NCNE	.
CAPTL10	.	NCNE	.
CAPTL11	.	NCNE	.
CAPTL12	.	NCNE	.
ENCBAL	.	NONE	.
DUCKFOOD	.	NCNE	.

LP Coefficients: Day hunt.

RHS		Activities	Stage=0	Stage=1	Stage=2
	Constraint or Resource				
OBJ	C	(Gross margin)\$	7,988.00	10,014.65	20,712.61
L	Landply	Ac.	31.37	31.37	31.37
L	H2OIRR1	ACIN.		413.46	826.92
L	H2OIRR2	ACIN.			912.86
L	H2OIRR3	ACIN.			1188.92
L	H2OIRR4	ACIN.			
L	H2OIRR5	ACIN.			
L	H2OIRR6	ACIN.			
L	H2OIRR7	ACIN.			
L	H2OIRR8	ACIN.			
L	H2OIRR9	ACIN.			1021.40
L	H2OIRR10	ACIN.		521.06	1042.12
L	H2OIRR11	ACIN.		467.41	934.82
L	H2OIRR12	ACIN.		446.08	892.16
L	LABOR1	HR.	45.00	65.67	406.43
L	LABOR2	HR.	30.00	30.67	145.64
L	LABOR3	HR.	20.00	14.50	89.44
L	LABOR4	HR.			
L	LABOR5	HR.			
L	LABOR6	HR.			
L	LABOR7	HR.			
L	LABOR8	HR.			
L	LABOR9	HR.	15.00	23.00	151.08
L	LABOR10	HR.	25.00	41.05	177.10
L	LABOR11	HR.	45.00	67.37	411.74
L	LABOR12	HR.	90.00	112.30	634.60
L	CAPTL1	\$	-2405.25	-2949.87	-11,626.63
L	CAPTL2	\$	159.60	159.60	2727.82
L	CAPTL3	\$	603.20	438.20	3128.58
L	CAPTL4	\$			370.00
L	CAPTL5	\$			370.00
L	CAPTL6	\$			370.00
L	CAPTL7	\$			370.00
L	CAPTL8	\$			370.00
L	CAPTL9	\$	84.60	324.60	4961.36
L	CAPTL10	\$	784.60	1490.23	27,641.24
L	CAPTL11	\$	-2405.25	-2849.96	-11,716.80
L	CAPTL12	\$	-4810.50	-6633.08	-37,878.16
L	DUCKFOOD				39,639.64

LP Coefficients: Season.

RHS		Activities	Stage=0	Stage=1	Stage=2
	Constraint or Resource				
OBJ C	(Gross margin)\$		2,979.30	3,622.28	5,273.04
L	Landply	Ac.	31.37	31.37	31.37
L	H2OIRR1	ACIN.		413.46	413.46
L	H2OIRR2	ACIN.			456.43
L	H2OIRR3	ACIN.			
L	H2OIRR4	ACIN.			
L	H2OIRR5	ACIN.			
L	H2OIRR6	ACIN.			
L	H2OIRR7	ACIN.			
L	H2OIRR8	ACIN.			
L	H2OIRR9	ACIN.			
L	H2OIRR10	ACIN.			521.06
L	H2OIRR11	ACIN.		467.41	467.41
L	H2OIRR12	ACIN.		446.08	446.08
L	LABOR1	HR.	4.00	24.67	24.67
L	LABOR2	HR.	4.00	4.00	26.30
L	LABOR3	HR.			
L	LABOR4	HR.			
L	LABOR5	HR.			
L	LABOR6	HR.			
L	LABOR7	HR.			
L	LABOR8	HR.			
L	LABOR9	HR.	2.00	2.00	2.00
L	LABOR10	HR.	4.00	4.00	30.05
L	LABOR11	HR.	4.00	27.37	27.37
L	LABOR12	HR.	2.00	24.30	24.30
L	CAPTL1	\$	31.20	87.68	87.68
L	CAPTL2	\$	70.00	70.00	127.05
L	CAPTL3	\$			
L	CAPTL4	\$			
L	CAPTL5	\$			
L	CAPTL6	\$			
L	CAPTL7	\$			
L	CAPTL8	\$	-3262.50	-5220.00	-7830.00
L	CAPTL9	\$	13.20	13.20	16.40
L	CAPTL10	\$	120.00	120.00	197.93
L	CAPTL11	\$	31.20	110.43	110.43
L	CAPTL12	\$	19.60	81.75	81.75
L	DUCKFOOD				39,639.64

LP Coefficients: Yearly.

RHS		Activities	Stage=0	Stage=1	Stage=2
	Constraint or Resource				
OBJ C	(Gross margin)\$		1,790.00	2,400.00	2,400.00
L	Landply Ac.		31.37	31.37	31.37
L	H2OIRR1	ACIN.		413.46	413.46
L	H2OIRR2	ACIN.			
L	H2OIRR3	ACIN.			
L	H2OIRR4	ACIN.			
L	H2OIRR5	ACIN.			
L	H2OIRR6	ACIN.			
L	H2OIRR7	ACIN.			
L	H2OIRR8	ACIN.			
L	H2OIRR9	ACIN.			
L	H2OIRR10	ACIN.			
L	H2OIRR11	ACIN.		467.41	467.41
L	H2OIRR12	ACIN.		446.08	446.08
L	LABOR1	HR.	2.00	22.67	22.67
L	LABOR2	HR.			
L	LABOR3	HR.			
L	LABOR4	HR.			
L	LABOR5	HR.			
L	LABOR6	HR.			
L	LABOR7	HR.			
L	LABOR8	HR.			
L	LABOR9	HR.	4.00	4.00	4.00
L	LABOR10	HR.	2.00	2.00	2.00
L	LABOR11	HR.	4.00	27.37	27.37
L	LABOR12	HR.	2.00	24.30	24.30
L	CAPTL1	\$	18.00	18.00	18.00
L	CAPTL2	\$			
L	CAPTL3	\$			
L	CAPTL4	\$			
L	CAPTL5	\$			
L	CAPTL6	\$			
L	CAPTL7	\$			
L	CAPTL8	\$	-2000.00	-2610.00	-2610.00
L	CAPTL9	\$	28.00	28.00	28.00
L	CAPTL10	\$	118.00	118.00	118.00
L	CAPTL11	\$	28.00	28.00	28.00
L	CAPTL12	\$	18.00	18.00	18.00
L	DUCKFOOD				39,639.64